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Education in Acoustics
Session 2pED: Teaching Methods in Acoustics

2pED6. A for play!
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The task was straightforward; design and build a playhouse to be raffled for a charitable organization. A team consisting of students, volunteers, and faculty banded together to not only meet the requirements but to exceed the typical preconceived ideas of a totally enclosed miniature home. Based upon the needs of juvenile clients, the design team focused more on "play" than on "house" when working out conceptual ideas. The playful design was based upon the enclosure being partially open to allow air flow, sunlight, and the ability for the inhabitants to have an aural connection to the outside. The idea of having partially open space on the lower level, a mere 5'-3" x 5'-3" footprint, flanked by stepped bands of cedar and cypress yielded a particular acoustical presence. The space is not only visually unique, but the selection of materials, how they were cut and assembled, and the scale in relation to a seated child enhance the fun factor by creating an enveloping and somewhat amplified acoustic. This project provided pedagogical opportunities within an atypical learning environment. The final inhabitable playhouse exceeded visual and acoustical expectations of a small space and prove acoustics "plays" an intrinsic role despite occupant age.

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The University of Oklahoma (OU) College of Architecture (COA) established a Summer 2012 course as a challenge for students and faculty to design and build a creative entry in the Court Appointed Special Advocates (CASA) of Oklahoma County, Inc. annual Playhouse Parade in which playhouses are raffled for charitable contributions. The initial assignment handed down to faculty (author of this paper) from university administration: design and build a playhouse within a 3 ½ week course and a material budget of $500, allowing opportunities for student centered learning to deliver beyond expectations. An ambitious team from the COA banded together to not only meet basic requirements of safety, time, and budget, but to offer an experiential alternative to preconceived ideas of a playhouse being a specific form or style. Sometimes marketed as a totally enclosed miniature home, a playhouse holds potential for design to be explored, expressed, and appeal to human senses beyond mere aesthetics. Although the class and project were not solely or particularly focused upon architectural acoustics pedagogy, the participants both exhibited and gained understanding through the design process and resultant inhabitable spaces.

DEFINING THE DESIGN – acoustics and aesthetics

The words used to describe a project and its associated function hold much potential for design genesis. As nouns or verbs, “play” and “house” can be defined in various ways and, therefore, conjure critical thought of how the intended function of a project influences the nature in which the project is developed and eventually occupied. The Merriam-Webster Dictionary defines “play” as the spontaneous or brisk activity of children and the stage representation of an action or story. The word “house” can be defined as a shelter or refuge; to contain an activity; and the audience in a theater or concert hall.¹ The word “play” can either be an adjective for the type of enclosure defining the activity or an integral part of the design concept and catalyst for a sensory environment. Based upon the behaviors of children, the design team focused more on “play” (in the active recreational sense) than on “house”, developing conceptual ideas into a multilayered interactive sensory experience – visual, physical, aromatic, and auditory. The team determined the playhouse will literally house years of memories innately linked to the defined space, materials, and sensory stimuli of the space(s).

Students, staff, and faculty teamed together in a collaborative effort to combine project requirements and creative thinking into one solution. The conceptual basis and design development of the playhouse project captured the raw inquisitiveness of creating through the active process of building. During the design process and consultation with classes of kindergarten, 1st, and 2nd grade elementary school children, the recognizable character of a fort emerged.

Figure 1. Photos show OU Architecture students consulting elementary school students about initial playhouse ideas.

The confines of a fort incite specific activity including various sounds associated with ranges of calm to rowdy behavior. Children can be quite vocal when playing, but there needs to be a delicate balance between playing out in the open for everyone to see and hear versus having a semiprivate space to encourage the world of make-believe.

Children assemble and disassemble toys into new and innovative constructs. This somewhat instinctive trait, highly prevalent during pubescent years, seems to be socially thwarted in most adult occupations later in life. When asked about the project, Ryan Williams, a 4th year architecture student shared, “Design concepts focused on qualities we believed children would enjoy in a playhouse. Words like whimsical, imaginative, modular, and dynamic were the springboard for the design. The twisting motion of the structure stems from the idea of modularity and whimsicality that provided a dynamic experience for children and allowed us to construct in a way that could be easily assembled and disassembled.”² The playful design was based upon the enclosure being partially open to allow airflow, sunlight, and ability for the inhabitants to have an aural connection to the outside – in a manner that allows the natural environment to “play” or interact within the enclosure. The process and resultant form of the playhouse defines various scales among the individually layered materials, the cumulatively stacked and twisting units, and the dichotomy between rigid and slotted surfaces.
The partially open space on the lower level, a mere 5’-3” x 5’-3” outer perimeter with median interior surface planes defining 4’-10” x 4’-10” (interior footprint) x 4’-3” (height) with an interior volume of approximately 99 cubic feet sitting on a 7’-6” x 7’-6” base platform, is flanked by walls and an overhead loft constructed from stepped bands of cedar, cypress, and translucent acrylic, salvaged from storm debris and donated from local construction sites. The walls are segmented in 1’-0” high sections, referred to as lifts. Each of the 7 main lifts rotates 7 degrees in plan above the previous lift. The individual pieces of cedar, cypress, and acrylic were designed and assembled to be flush on the exterior surface of the walls and floor of the second level, allowing the interior face of the walls and under side of the overhead plane to undulate in and out of the partially enclosed space. The cedar and cypress members are 1 5/8” tall, while the acrylic is approximately 3/8” tall. The interior faces of the wood members step in and out approximately 1” from the median line, defining a maximum displacement of 2” in and out from the face of an adjacent wood member. The space is not only visually unique, but the selection of materials, how they were cut and assembled, and the scale in relation to a seated child enhance the fun factor by creating an enveloping and somewhat amplified acoustical environment.

**Figure 2.** Plan views, starting at the first lift on the base, show the twisting of lifts in relation to previous lifts moving upward.

**Figure 3.** A series of renderings and a site photo shows the stepping and twisting of form in both section and elevation.

**ACOUSTICAL SENSATIONS**

Design always produces an acoustical environment as a result of material and aesthetic details. The staggered design of the playhouse was an innovative way to use dimensional materials in an atypical manner and an avenue that yielded a particular acoustical presence in the lower level distinctive from the upper level and exterior alcoves. The resultant acoustical sensation is not an anomaly in the world of small room architectural acoustics, but it does provide a unique learning environment for inhabitants, regardless of age. The playhouse is a physical demonstration of an acoustically fun space and has become a teaching tool to introduce and educate students about acoustics. Students not only see but also hear the connection between materials and the resultant environment, seamlessly combining acoustics and aesthetics through the undulating layers of wood and acrylic.

The design literally houses a particular auditory sense that begins a discussion of basic acoustical terminology such as diffusion, reflection, absorption, and frequency. Additionally, students are subsequently introduced to associations of clarity, envelopment, and intimacy due to early and strong frontal reflections, lateral reflections, and the close proximity of surrounding walls. The team believes the acoustical presence of the lower level would not be the same if the interior surfaces were plumb and stacked in a planar fashion or if the apertures were different in size and/or location. In approximation, the wall surfaces equate to 82 square feet (sf) while the 4 sf opening above the door and the 6 sf opening in the loft floor equate to 10 sf of openings in the 128.5 sf total interior surface area. This equates to 7.8% open surface area.
The variation of materials and intentional deviation from the parallel planar surfaces allows diffusion when compared to direct reflections from planar surfaces. The 10 sf openings vented to the outdoor environment are considered ideal absorbers with an NRC of 1.0, direct paths for some exterior and environmental sounds to exist and a portion of the interior auditory presence to be heard outside the enclosure. The openings are believed to diminish a majority of standing waves within the lower level.

Aesthetics and acoustics collide in the dichotomy between exterior and interior faces of the enclosure. The spatial articulation and overall geometry of the twisting single wythe wood lifts provide two distinct surfaces to one material and allows an enhanced acoustical quality for speech intelligibility that is undeniably pleasant to the speaker and listener. The cedar and cypress walls of the playhouse not only provide the aromatic presence of natural wood, but the layers of cedar, cypress, and acrylic also affect the timbre and character of the spoken voice.

The proximity of undulating surfaces defining the playhouse’s lower level provide diffusion and filtered frequencies from acoustical interference, altering the perception of voices. Students are exposed to acoustical lessons in what may typically be thought of as sound effects, expressed in real time similar to what Ethan Winer states about flanger and phaser effects.

Because the peaks and nulls in small rooms occur at regularly spaced frequency intervals, the net result can be considered a type of comb filter. This is exactly how flanger and phaser effects work, except in this case the filtering happens acoustically in the air as the waves collide, reinforcing or canceling each other. The general term for this phenomenon is acoustic interference.
Bert Stoltenborg goes on to state, “A diffuser, especially a slotted type like a QRD… is a bunch of small band resonators and when you stand close to them and talk into them, you hear resonances, you hear them colour your voice.”

Figure 6. Initial frequency responses of prerecorded consistent noise played at 85 dB$_A$ (approximately 82 dB$_C$) 1’-0” from source shown on a 20 – 20,000 Hz spectrum. a. Upper left image shows frequency responses of recorded noise sample 5’-0” from the noise source in a mostly absorbant room similar in size to the lower level of the playhouse. b. Upper right image shows frequency responses of recorded noise sample 5’-0” from the noise source inside the lower level of the playhouse. c. Lower left image shows frequency responses of recorded noise sample adjacent to the noise source in a mostly absorbant room similar in size to the lower level of the playhouse. d. Lower right image shows frequency responses of recorded noise sample adjacent to the noise source inside the lower level of the playhouse. Upper images show little difference between room surfaces, while lower images show variation of frequencies defining change in acoustical perception at adjacent wall surfaces within the playhouse. While data is considered inconclusive at identifying specific comb filtering, changes in frequency concentrations experienced by playhouse inhabitants are expressed. Acoustical data was collected upon completion of the playhouse installation. The frequency responses were recorded digitally via a stereo microphone and then lined into a spectrum analyzer to show graphically the frequency ranges and heaviest locations of concentration.

Figures 5 and 6 show the irregular interior surfaces (stepped and layered cedar, cypress, and acrylic) and initially collected frequency responses. Due to the difficulty of making measurements with currently available equipment and the location of the playhouse approximately 45 miles from campus, the design team is not convinced the current method of testing is conclusive. Members of the design team reviewed the completed project with Mr. Russ Berger and concluded testing will continue in future semesters with students for conclusive results. As a small room expert, Mr. Berger will contribute to the methods/metrics rubric of testing the interior space(s) compared to an enclosed version of the lower level and another enclosure with flat/planar wall surfaces. The playhouse will continue to be a destination for teaching acoustics in various courses (Design Studios, Materials and Form, and other courses focused on architectural acoustics) associating physical data collection to spatial and acoustical terminology.

TEACHABLE MOMENTS

The CASA Playhouse project continues to be a popular discussion topic among students, staff, alumni, and faculty at The University of Oklahoma. The final result has also been publicized locally with positive feedback. Those who have visited the playhouse, either at the COA model shop during fabrication, Penn Square Mall in Oklahoma City during the Playhouse Parade, or at its current backyard home, comment about the structure and how
their voice sounds within the lower level. The unique learning environment spans outside the classroom and curriculum. A second year architecture student, Alma Sandoval, describes her experience with the playhouse as:

I was a freshman in the College of Architecture at the time of the playhouse class. I didn't know anything about acoustics in the design realm prior to the Playhouse class or Materials class in which Professor Butko also teaches. I recall the first time I sat in the corner of the playhouse under the loft; I was immediately introduced to a new world of interest. Suddenly my voice seemed amplified in my ears, and the way my voice sounded was noticeably different than normal. The lower level is a cool little space with a unique acoustical presence in direct opposition to the open nature of the upper level. 

Ms. Sandoval and the other students who participated in the playhouse project have only just begun to learn about acoustics; as many of the participants are either currently enrolled in the Spring 2013 Architectural Acoustics course or have expressed interest for future course offerings. The entire playhouse project process, including the “ah-ha” moments, became more than a class or volunteer opportunity. Similarly, this event can be defined within the definition of the knowledge requisite for the exercise of skill in design, as explained by A.H. Marshall in the article, “Undergraduate Courses in Acoustics for a School of Architecture.” Marshall states the relationship between acoustics and a design process must be identified, “first in terms of the process, and second in terms of the aesthetic judgments which by definition are integral with “design.” Students had and will continue to have “light bulb” moments from this project. The inhabitable space became a catalyst for students to become interested in acoustics, proving that moments of education can be the result of being receptive to immersive learning.

![Figure 7](image)

Figure 7. The simple smile and enthusiasm of a child upon hearing his own voice in the lower portion of the playhouse. Image taken from a video recording.

Perhaps the children who inhabit this playhouse will someday equate the connection between aesthetics and acoustics. They, too, will understand that their playhouse offers a balance for visual, auditory, and kinesthetic experiences. For now, the young children are literally surrounded in a particular acoustical environment that will link to memories. Somewhere in these memories of playing, they will relate the atypical acoustical environment to the playhouse and begin to make the connection to materials and form. They may not realize the reasons now, but there is an acoustical, visual, and memorial union.

**CONCLUSION**

A for acoustics; A for aesthetics; A for articulation; A for asymmetrical; A for atypical - above all, students received a final grade of A in the class. Their diligence for harnessing and combining materiality and form into a showcase of architectural ingenuity, auditory interaction, teamwork, meeting deadlines, and ultimately constructing something that appeals to people of all ages, demonstrated ability to produce an inhabitable piece of art. Everyone involved (CASA, raffle winner, COA, and students) is still overjoyed with the high level of conceptual, spatial, and physical craft. To someone outside the design community, an entry in the CASA Playhouse Parade might have appeared straightforward, but architecture is not predictable nor limited to two or three-dimensions. The various avenues of exploration inherent in the words “play” and “house” challenged students to focus energy and design intent on how the simple stacking of the proverbial found objects of salvaged and donated materials could make a particular place for children to socialize among peers, share with their friends, and ultimately call their own.

Design prowess supersedes preconceived ideas and allows design to be an art form, able to house various levels of visual, spiritual, emotional, auditory, and thought-provoking evaluation. The final inhabitable playhouse exceeded the team’s visual and acoustical expectations of a small space and proves acoustics “plays” an intrinsic role despite occupant age. The simple expressions of a child hearing the acoustical quality of the space speaks for
itself. The younger the better when it comes to acoustical education. Learning becomes something intentional and visual as explained in the book, “Places of Learning” by Elizabeth Ellsworth. Ellsworth openly discusses learning as an undeniable look of simultaneous absorption and self-presence; being part of an experience, not compliance. Specifically, she states that the look has become “the face of Learning with a big “L” – Learning itself.” 7 The best way to learn is to experience personally the task at hand, realizing how every decision impacts inhabitable space(s).

The study of architectural acoustics is generally concerned with the material selection and the shape of the prescribed space. This project embodies the intrinsic link between material selection, form, and acoustics, proving innovation and craft can yield a successful acoustical environment. Variety of materials, variety of surface articulation, and variety of shapes allows aesthetics and acoustics to exist within the same envelope.

The acoustical environment itself mirrored the words and ideas we originally set out to capture for the project. It is a major portion of the experience. There is something to be said about the connection between aesthetics and acoustics - for example, the way in which the stepping and rotations of each layer create an amplifying effect on sound within the space. The rotation allows for a whimsical appearance while simultaneously creating an acoustical environment that allows the occupant to be in a special whimsical space.8 - Ryan Williams, 4th yr. architecture student

Testing and comparative analysis can show/prove empirical data, but there is also the human emotion and appreciation for art. The playhouse has become a playground for children, students, and acousticians alike and will continue to be studied with the interior acoustical environment evaluated further.

REFERENCES

2 Williams, R., Email interview, (8 June 2012).
8 Williams, R., Email interview on 20 Jan. 2013, (2013).